# Planetary Boundary Layer Estimation from Doppler Wind Lidar Measurements, Radiosonde and Hysplit Model Comparison


**Moreira, G. de A. (1), Marques, M. T. A. (1), Nakaema, W. M. (1), Landulfo, E. (1)**

(1) CLA, IPEN/CNEN, Center for Lasers and Applications, Av. Prof. Lineu Prestes, 2242, Cidade Universitária, São Paulo – SP – Brazil, 05508-000

Corresponding author email: gregori.moreira@usp.br


## 1.Introduction

Remote sensing devices has been largely utilized in environmental applications [1]. They have been appointed by many authors [1,2] as one of the best tools to obtain information of atmosphere, because they provide good description and characterization of the troposphere, mainly because they have a good spatial and temporal resolutions.

When it comes to wind, wind Doppler lidar deserves to be highlighted, because it enables different types of studies, which vary from observations of vertical wind profile until the detection of turbulent phenomena [1,3], so that, this device has been largely used in academic studies and in commercial applications.

## 2.Methodology

The measurement campaign was held in Ressacada's Farm (27°40'S, 43°30') Santa Catarina State - South of Brazil, during December 2014. Located 1.6 km southeast from the international airport of Florianópolis (SBFL) where the radiosondes are launched.

Fig.1. Measurements campaign location.

### 2.1Instruments

| Performances | WLS70 |
|---|---|
| Range | 100 to 1500m |
| Accumulation Time | 7 s |
| Data output frequency | 0.1 Hz |
| Probed length | 50m |
| Scanning cone angle | ~ 15° |
| Speed Accuracy | 0.3m/s |
| Speed range | 0 to 100m/s |
| Direction Accuracy | 1.5° |
| Data Availability | > 95% up to 500m |

Table.1. Lidar Windcube WLS70 performances.

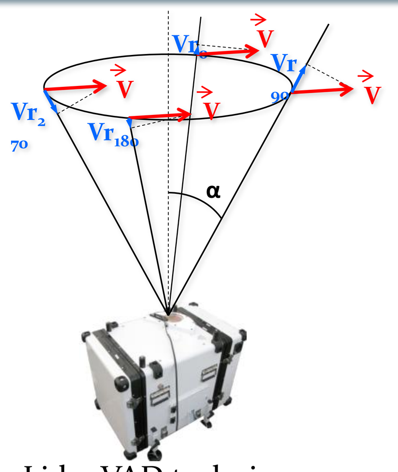
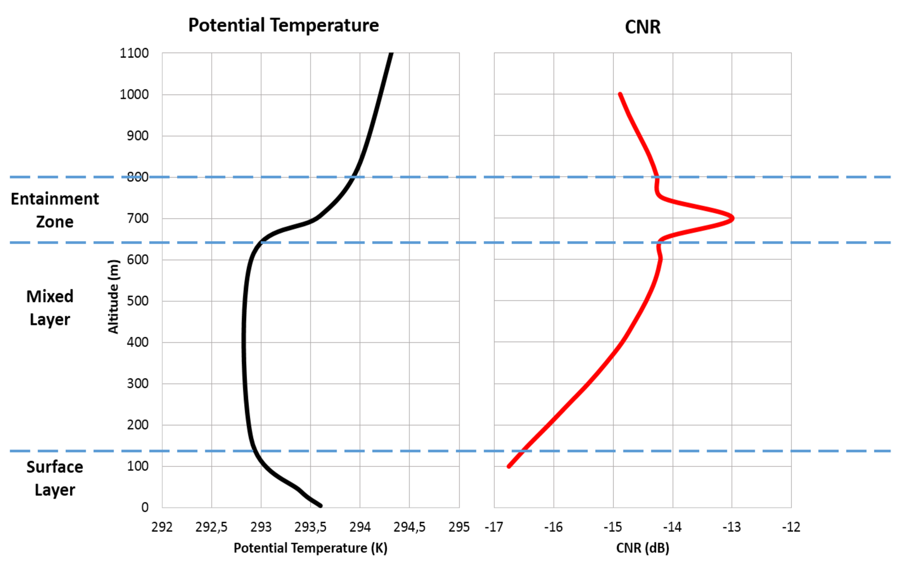


Fig.2. Lidar VAD technique scan.

### 2.2 Planetary Boundary Layer (PBL) Height

The signal received by lidar is coming from inhomogeneities in atmosphere, which are characterized by the refractive index structure parameter ($C_n^2$) [4]. Wyngaard [5] showed that it is possible to use $C_n^2$ value to find the PBL height in convective situations, because it has a peak in top of this layer. Van Zandt [3] evinced the proportionality between $C_n^2$ and SNR range-corrected values, so it is possible to conclude that we can use SNR values to detect PBL height [4], being that the top of PBL is equivalent at maximum value of SNR profile.



Graph.1. Example data of the CNR method to the PBL location.

### 2.3 Bulk Richardson Number

The BRN is a relation between potential and kinetic energy [6], being that, it enables to detect different turbulent regimes in atmosphere. PBL has turbulent activities more intense than free atmosphere, so that, PBL has different values in these layers. Therefore, if the standard value of critical BRN *(CBRN)*, in transition of these layers, is known, it is possible to estimate the PBL height. Although there are some divergences about more precise value, often the range is about 0.25 to 0.30 [6]. In this paper the value adopted is 0.25.

$$BRN = \frac{\frac{g}{\theta_{vs}}(\theta_{vz} - \theta_{vs})(z - z_s)}{(u_z - u_s)^2 + (bu_*)^2} \quad \text{Eq.01}$$

The information used to obtain BRN come from radiosonde data (12 UTC) and Hysplit model (a point every 3 hour), which provide radiosonde emulated data each 3 hours.

## 3.Results and Discussion

The lidar and the radiosondes observations represent different measurements of the wind field, the lidar winds are averaged in time and space according to the VAD technique, in contrast, the radiosonde averages the wind along the balloon trajectory. This effect, coupled with atmospheric variability induces differences in the wind observations not caused by instrumental errors. [2] The Fig. 03 shows the wind profile observed by the lidar, radiosonde and Hysplit, the different mechanisms used to calculate the PBL height.

The Fig. 04 shows a comparison between the three mechanisms used to obtain PBL height: BRN (Hysplit and radiosonde) and CNR. In background of this graphic, it was inserted a parameter named *Data Availability*. This parameter corresponds to the ratio of measurements points accepted by built-in data filters over the complete set of measurement that took place during the averaging period.

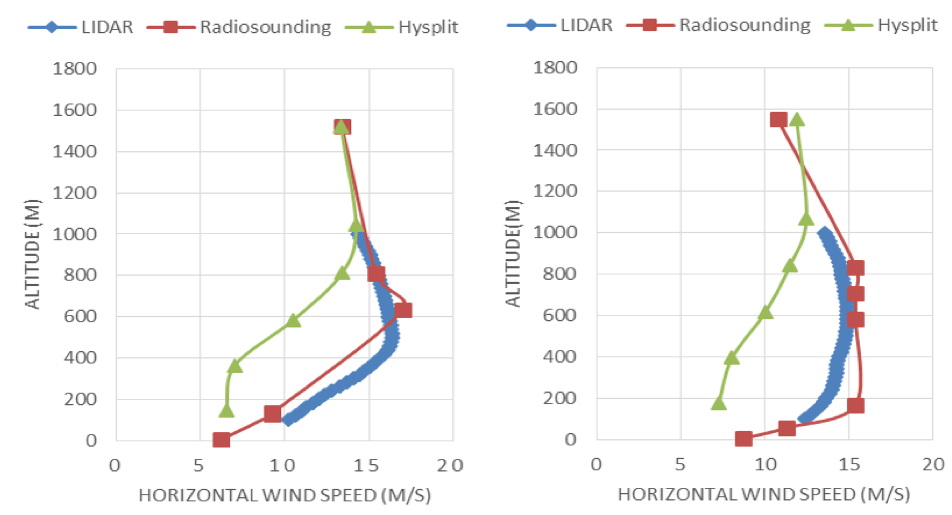


Fig.3. Horizontal wind profile – Ressacada's Farm – Brazil – 23/12/2014 00 UTC (left) 12 UTC (right).

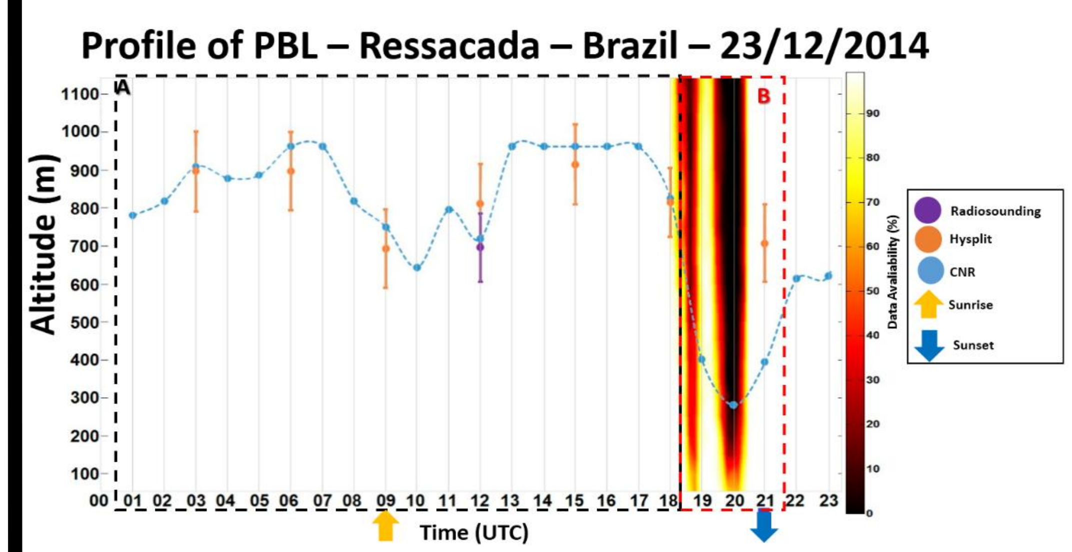


Fig.4. Profile of the PBL – Ressacada's Farm – Brazil – 23/12/2014.

The case A comprehends since 01 until 18 UTC. Along this period, the data availability keeps high values and there is high proximity among values obtained from lidar data and BRN from radiosonde and Hysplit. The Fig. 05 shows a comparison among these three mechanisms at 12 UTC. Due to small quantity of points in radiosonde data and low spatial resolution, sometimes the comparison between Hysplit and radiosonde is not so near.

Because this uncertainty, it was inserted error bars created according to average of two heights near point selected. BRN points calculated by Hysplit and radiosonde have similar profiles and they are spaced from each other thereabout 126 m. These two points are near height obtained from CNR method, but radiosonde data has higher proximity (26 m) than Hysplit (100 m). Along all period, the PBL heights obtained from CNR method are inner range of each point generated by Hysplit data.

The case B covers some minutes after 18 until 21:30 UTC. During this period the data availability has small values, so that, the correlation between Hysplit and CNR Method is small, the difference between them is 345 m.

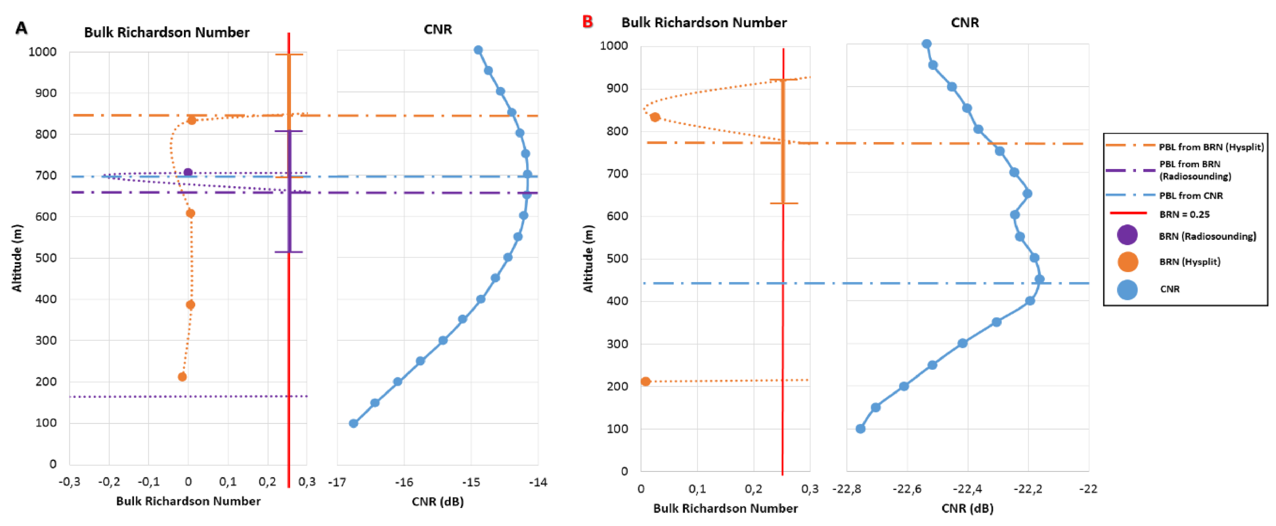


Fig.5. Comparison among lidar, radiosonde and Hysplit. Case A (Left) - Case B (Right).

From these two situations, it was possible to observe the high skill of lidar data to provide PBL height, the majority of points are situated inner the range of BRN data, with the exception of point situated in case B, as discussed.

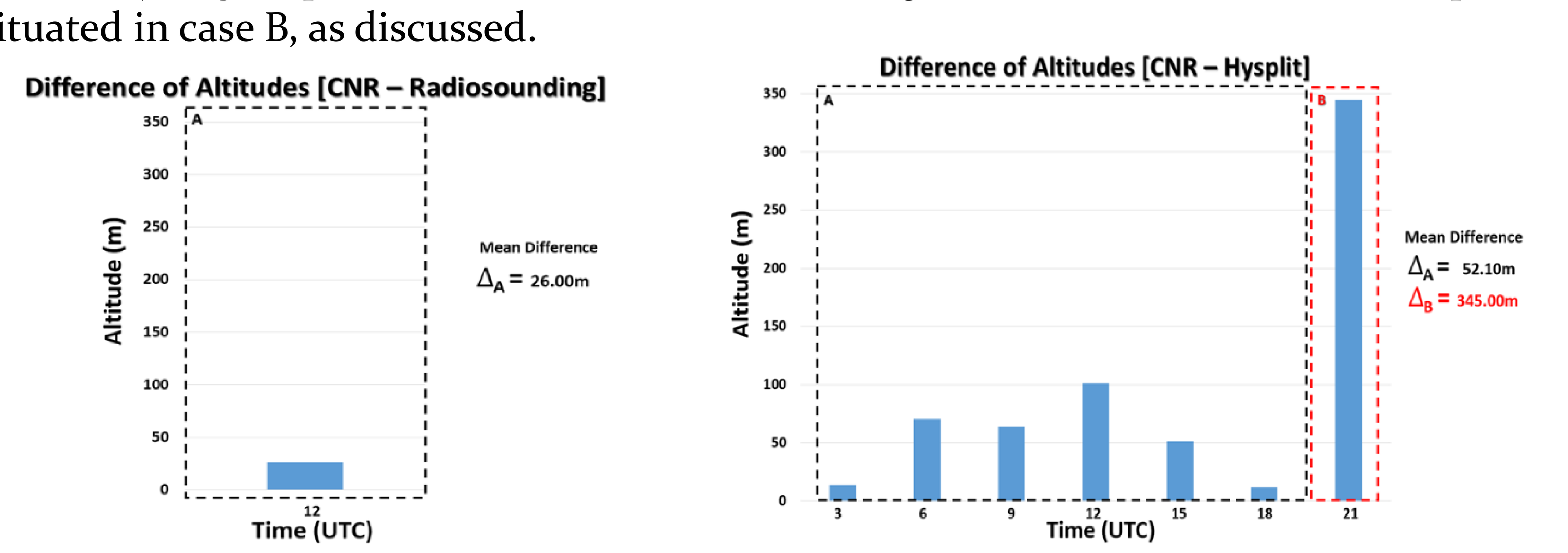


Fig.6. Difference between PBL height from lidar and Hysplit (right) and from lidar and radiosonde (left).

## 4.Conclusion

The value of PBL height obtained by the wind Doppler lidar has a significant proximity to the value obtained for the radiosonde that we use here as a reference. In the same time, the Hysplit model gives values with reasonably proximity as obtained from CNR method, considering the errors bars. In accordance to this, as we can see in Fig. 01 through the horizontal wind speed vertical profile, there is a better correspondence between the lidar and the radiosonde, despite its technical limitations, than the lidar and the Hysplit model.

However, for most of the moments, the Hysplit model is the only method we can compare with lidar results and it shows an acceptable proximity except in the case where the data availability is low.

In order to have better and accurate results we see the necessity to extend the period of comparison and at the same time improve the temporal resolution of the radiosonde, but, as a limitation out of the boundaries of this study, an option is to improve the modeling results to the comparison.

## 5. References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